COST REDUCTION IN DEVELOPMENT OF ADEOS-II MISSION OPERATION SYSTEMS

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ABSTRACT

ADEOS-II (Advanced Earth Observing Satellite-II) was launched successfully on December 14, 2002 by NASDA with H-IIA rocket flight IV and named as Midori-II. It carries five Earth observing sensors including Global Imager (GLI) and Advanced Microwave Scanning Radiometer (AMSR) developed by NASDA. All Earth observation sensors were turned on by the end of January 2003 and working well.
For ADEOS-II mission operation, NASDA prepared AMOS (ADEOS-II Mission Operation System) reflecting ADEOS (Advanced Earth Observing Satellite; Midori) and other experiences.
To reduce the cost of the development, NASDA introduced the idea of "Design To Cost (DTC)". This means to set the total cost as target in very initial phase and assign the proper cost to each element. "Element" includes system development and also testing, training and operation.
Regarding the cost of operation, NASDA set "automation" as the primary target in a design of AMOS. Introduction of "network on-line interface" was the one of the key.
In case of AMOS development, cost reduction did not cause a low performance system, but realize an operator-friendly and sophisticated one

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1. INTRODUCTION

1-1 ADEOS-II Overview

Advanced Earth Observing Satellite-II (ADEOS-II) was launched on December 14th, 2002 by National Space Development Agency of Japan (NASDA) with the NASDA H-IIA rocket. ADEOS-II mission life is three years according to its design.

The major purposes of the ADEOS-II mission are to enhance the earth observation technologies and to provide the global observation data succeeding to the ADEOS mission. These data will contribute to the study of the global climate and the environmental changes which are taken an increasing concern in all over the world. ADEOS-II carries five Earth observing sensors (see Table 1) that accumulate global data 24 hours a day.

Table 1 Sensors and their providers

Sensor/System Name	Acronym	Sensor Provider
Global Imager	GLI	NASDA
Advanced Microwave Scanning Radiometer	AMSR	NASDA
Improved Limb Atmospheric Spectrometer – II	ILAS-II	NIES (*1)
SeaWinds	SeaWinds	NASA/JPL (*2)
Polarization and Directionality of the Earth's Reflectance's	POLDER	CNES (*3)
Data Collection System	DCS	NASDA/ CNES (*3)

*1: National Institute of Environmental Studies (Japan) [http://www.nies.go.jp/]
*2: NASA Jet Propulsion Laboratory [http://www.jplnasa.gov/]
*3: Centre National d'Etudes Spatiales (France) [http://www.cnes.fr/]

1-2 ADEOS-II Mission Operation System Overview

1.2.1 System Configuration

The observed Raw data of ADEOS-II down-linked to NASDA Earth Observation Center (EOC) or overseas ground stations (Kiruna, Alaska, and Wallops) are processed to Level-0 and delivered to sensor providers mainly with on-line manner. Data acquisition and downlink are done in an orbit-by-orbit manner with ADEOS-II onboard Mission Data Recorders (MDR) for near real time data application. Each sensor provider perform Level-1, 2, and 3 processing to create the science products and the products are archived and delivered to the users.

1.2.2 Operation Management

Mission Management and Operation System (MMO) manages the mission operation of ADEOS-II space observatory and executes some steps according to the procedure with the whole ground stations and related agencies.

MMO generates data acquisition plan (how to use Inter Orbital Communication System (IOCS) and/or Direct Transmission function (DT), how to use three MDR etc.) according to the IOCS link assignment information and coordinates with Tracking And Control Center (TACC), overseas ground stations and the related agencies. During this coordination, some files are exchanged via network. Based on these results, MMO determines the final version of the operation plan and makes mission operation information file for data receiving, recording and processing according to the results. The operation plan is generated every week for routine operation.Other than EOC, three ground stations; Alaska/USA (ASF), Wallops/USA (WFF) and Kiruna/Sweden (KRNS) are used for receiving mission data via X-band. The received data, except for GLI -250m resolution data, some of GLI-1km resolution data and POLDER data, are processed to Level 0 data and transmitted to EOC and related agencies via network for near real time application. All of the RAW data recorded onto D-1 cassette and shipped to EOC on weekly basis for further processing.

1-3 ADEOS-II Science Data Management

The ADEOS-II science dataset consists of NASDA core sensor products and non-NASDA sensor products by sensor providers. NASDA and each sensor provider will separately accomplish data management including data processing, archiving and distribution service for data users. The interface with data users will be realized on the basis of global internet connection providing with the functions of catalog information search, data ordering, and on-line and/or off-line data delivery, together with the associated observation information.

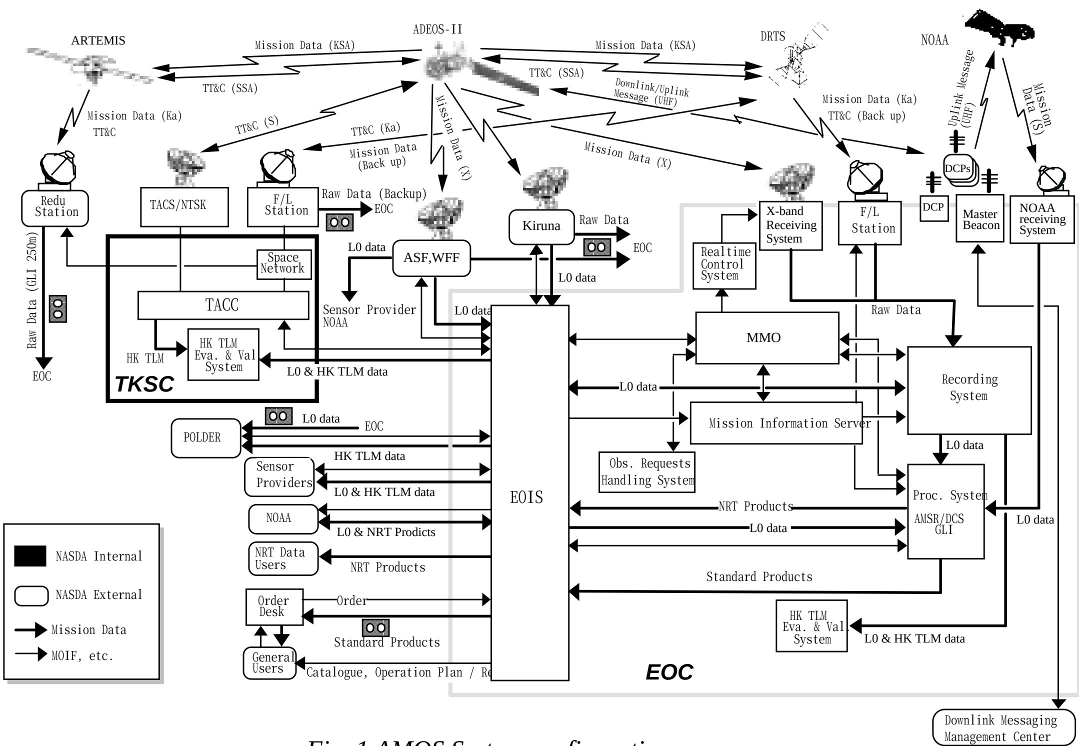

Fig. 1 AMOS System configuration

Table2 Data level definition for ADEOS-II

Level	Definition
Raw	Multiplexed and CCSDS packet data
Level 0	✓ Time ordered source packet data
Level 1A	<For GLI > Data with radiometric and Geometric correction coefficients <For AMSR > Data with radiometric coefficients and geometric information
Level 1B	<For GLI > ✓ Radiometric and geometric corrected data ✓ Band registrations done <For AMSR > ✓ Radiometric corrected data ✓ Brightness temperature
Level 2	<For GLI and AMSR> physical contents (such as Sea Surface Temperature)
Level 3	<For GLI and AMSR> Binned data or mapped data

Table 3 Data delivery to sensor providers

Data Type	Receiver	Requirement Delivery Time
SeaWinds L0 science data	SeaPAC	Within 160 min after observation
ILAS-II L0 science data	NIES	Within 5 hrs after downlink
POLDER L0 science data	CNES	(Weekly delivery by media)
ADEOS-II/ARGOS DCS L0 global data	CNES	Within 3 hrs after observation Local data: within 10 min after downlink
NOAA/ARGOS DCS L0 Regional Data	CNES	Within 10 min after downlink

1.3.1 GLI Science Product

GLI is an optical sensor that observes the reflected solar radiation from the Earth's surface, including land, oceans and clouds and/or infrared radiation with a multi-channel system for measuring the biological content, such as chlorophyll, organic substance, and vegetation index as well as temperature, snow and ice, and cloud properties. Observed GLI data downlink to ground stations are subject to Level 1 and higher processing at NASDA EOC. The amount of GLI Raw data is about 55GB a day. Data for specified regions for near-real-time use are collected in NASDA EOC for the generation of global GLI science data set.

The Raw data of specified regions for near-real-time use are collected in NASDA EOC via on-line manner for the immediate data processing. The near real time products will be routinely delivered to couple of operational data users. The delivery of GLI science data set and near real-time products is done via Earth Observation Data and Information System (EOIS) at NASDA EOC.

GLI Level 1 products are planned to be open to public in Dec. 2003.

1.3.2 AMSR Science Product

AMSR detects microwave emissions from the earth's surface and atmosphere. Various geophysical parameters, particularly those related to water (H_2O), are estimated from AMSR data. In addition to the proven parameters, such as water vapor, precipitation, and sea surface wind speed, novel geophysical parameters, including sea surface temperature and soil moisture, are expected to be retrieved by using new frequency channels. Conical scanning is employed to observe the Earth's surface with a constant incidence angle of 55 deg.

All AMSR data are accumulated at NASDA EOC via on-line manner and immediately processed with as soon as possible basis. The amount of AMSR Raw data is about 1GB per day. Near real time products will be delivered to the operational data users via on-line manner. The delivery of AMSR products is done via NASDA EOIS.

AMSR Level 1 products are planned to be open to public in Sep. 2003 and higher-Level products in Dec. 2003.

1.3.3 Data service of NASDA EOIS

User service at NASDA EOIS is categorized to three types: catalog information service, off-line data distribution service (on media), and on -line data distribution service (via network). Catalog information is accessible via internet by using EOIS user interface software (EUS). PI and relevant agencies can use EUS graphical user interface (GUI), which supports Windows Macintosh /Unix environment. Public users can use EUS WWW gateway at:

http://www.eoc.nasda.go.jp/catalogue/catalogue_e.html

The data-ordering function is available but limited only to the PIs and the relevant agencies.

Data availability for on-line delivery is limited to specified products (most of Level 3 products) and period (last 6 months). URL is:

http://drs.eoc.nasda.go.jp/index_e.html.

Science products of GLI and AMSR will be available for delivery on media. And the limited products will be also available via online also.

2. Design To Cost

In the development of ADEOS-II Mission Operation System (AMOS), NASDA introduced the idea of “Design To Cost (DTC)”.

2-1 Premises and Target

The development of mission operation system highly depends on the specification of the satellite and operation requirement. And also the cost has been already defined as a part of the project budget. On the other hand, most of systems are unique and needed to be newly developed as operational system. NASDA is to manage and integrate the AMOS project with related agencies and system developers.

Under these premises, NASDA set the following points as target of the overall system.

<Target 1> To complete the development within the assigned budget

<Target 2> To realize the system specification satisfying the mission requirement

<Target 3> To establish the open system including other domestic and foreign agencies

<Target 4> To complete the development (including testing) and operation preparation by ADEOS-II launch

2-2 Design philosophy

2-2-1 System Specifications

As the specification of developing AMOS, the following points were defined.

(1) Global observation is the most important characteristic for ADEOS-II mission operation. Therefore AMOS should aim for automatic and autonomous system to satisfy the global observation. The details of this subject are described in Chapter 3.

(2) Overall design and cost including system development, operation and maintenance should be optimized.

(3) External resource should be used as much as possible for oversea stations as a part of out-sourcing.

(4) GLI and AMSR processing system should be developed incrementally. The small size system initially installed and later the system should be extended according to the actual requirement. This enables the optimization of processing system size and cost because the accurate estimation before operation start is very difficult in conjunction with science algorithm development procedure.

(5) Functionally distributed ground station network should be introduced. Mission data should be acquired at four stations (including oversea stations) and each station is responsible fore level 0 data processing and distribution to users.

2-2-2 Major Technology

To make best use of the limited budget, NASDA identified several as “important technical issues”.

(1) Ground receiving station design required for global data acquisition and data utilization in near real time manner.

(2) Analysis about mission operation load to each ground system

(3) Optimization in designing composite data acquisition system of Data Relay Test Satellite (DRTS) and oversea stations.

(4) Level 0 processing, file specification and data transmission method optimized for CCSDS packet format.

(5) Data interface among each system using network (such as LAN, WAN) and other Information Technology (IT).

Regarding these issues, cost-effectiveness was evaluated at first and decided the introduction. NASDA gave the priority for these issued on assigning the budget.

2-2-3 Program Management

Program management is also very important for the effective system development.

NASDA set three critical points for this development.

(1) Interface design

The following points should be followed

- ✓ Clarification and documentation of each interface
- ✓ Classification between common specification and individual specification
- ✓ To clarify the specification in early stage of system development
- ✓ Clarification of testing approach
- ✓ Confirmation of total system operability using simulation test

(2) Configuration Control

To avoid misunderstanding in design and detect anomalies early, configuration should be strictly managed.

(3) Promotion of mutual understanding

Interface coordination meetings should be held periodically to keep good relationship and mutual understanding.

2-3 Evaluation

The core of this system consists of five points shown in 2-2-2 and focusing on these points are proved to be successful approach.

3. Automatic operation

As for the system newly developed for ADEOS-II mission operation, one of the fundamental policies was “automatic operation as much as possible”. Because 24 hours per day, 365 days per year operation is nominal for ADEOS-II mission operation and the cost for operators are increasing year by year, automatic operation is necessary to minimize operator numbers.

In this section, one of the ADEOS-II cost reduction example by automation is shown comparing with ADEOS mission.

3-1 Data acquisition and Level 0 data processing

3-1-1ADEOS Mission

During ADEOS mission, only X-band was used for mission data downlink. EOC, ASF and WFF received data and recorded them onto D-1 cassette tapes. RAW data tapes were shipped to EOC periodically.

All Level 0 data was generated at EOC by reproducing D-1 tapes. Level 0 data was recorded onto D-1 tapes and delivered to ADEOS processing system.

Data downlink at EOC was about 4 times per day. Therefore EOC recording system operator had to manage the following things.

- RAW Data recording (4 time/day)
- RAW data reproducing for L0 data processing and Level 0 data recording onto D-1 cassette (4 times/day for EOC data, additional times for ASF/WFF data)
- Level 0 data tape delivery to the processing system

EOC recording system was operated 24hours/day, 365days/year, and one operator was assigned to one shift (= 8hour operation).

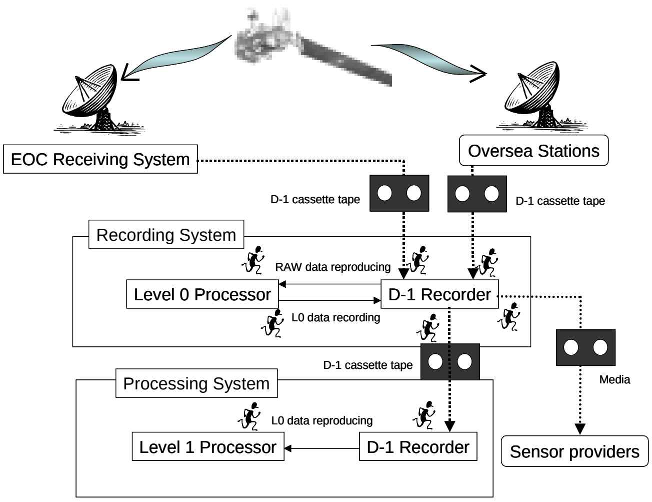

Fig. 2 ADEOS mission operation (Data acquisition ~ L0 data delivery)

3-1-2 ADEOS-II Mission

Because Data Relay Test Satellite (DRTS) can be used for ADEOS-II mission operation, two kinds of data downlink are available. At EOC, ADEOS-II mission data is downlinked fourteen times per day, about every 100 minutes via DRTS. And also there are four time X-band downlinks per one day at EOC. Furthermore, mission data is also downlinked to ASF (10 times/day), WFF (3 times/day) and KRNS (6 times/day). As a result if ADEOS-like operation method is applied, EOC recording system operator has to manage the following items.

- RAW Data recording (14 time/day)
- RAW data reproducing for L0 data processing and Level 0 data recording onto D-1 cassette (18 times/day for EOC data, additional times for ASF/WFF/KRNS data)
- Level 0 data tape delivery to the processing system

To do the above task continuously, additional operators (two or more) are needed comparing to ADEOS Recording system.

Therefore NASDA decided to change the operation flow. The followings are the changing points.

<Point 1> Level 0 data processing

For ADEOS-II mission operation, Level 0 data is processed without D-1 reproducing. This also enables quick processing and delivery of Level 0 data.

<Point 2>Level 0 data delivery from oversea stations

Except for GLI and POLDER data, mission data is processed to Level 0 at each ground station and deliver to EOC, sensor providers and specific users via network. This eliminates additional Level 0 processing at EOC.

For this change, new network was installed between EOC and each ground station.

<Point 3>Level 0 data delivery to ADEOS-II processing system

This eliminates Level 0 data recording task and off-line (D-1 tape) interface between recording system and processing system.

The cost reduction point of this change is the cost of D-1 cassette tapes.

As already stated in Chapter 1, total data volume of GLI data acquired per one day is about 55GB. For AMSR, data volume is about 1GB per one day. One D-1 cassette tape can store up to 35 GB. Therefore, two D-1 tapes for GLI and one D-1 tape for AMSR are needed every day and 1,095 tapes are needed for one year if Level 0 data is exchanged using D-1 tapes.

Instead of using D-1 tapes, new network between ADEOS-II recording system and processing system was installed same as <Point2>.

As a result of <Point 1> ~ <Point 3>, only one operator per one shift is assigned to ADEOS-II Recording System.

This leads to cost reduction for operators.

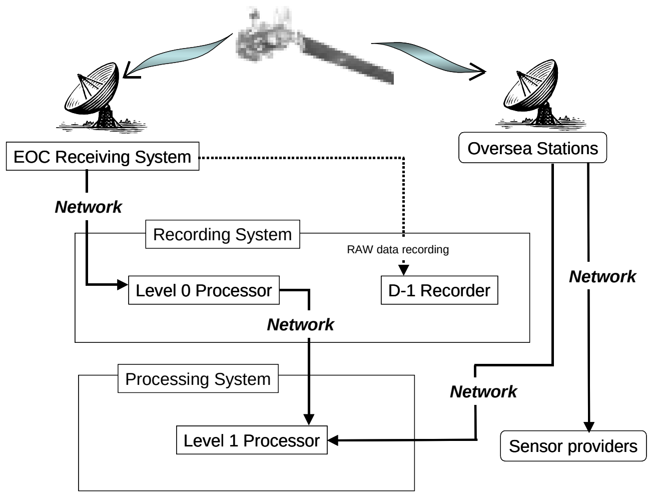

Fig. 3 ADEOS-II mission operation
(Data acquisition ~ L0 data delivery)

3-2 Standard Processing (Level 1 ~ 3)

3-2-1 ADEOS mission

For ADEOS mission, Level 0 data was delivered from Recoding system using D-1 tapes. Therefore manual operation is necessary to start Level 1 processing. Furthermore, the processed data (Level 1~ Level 3) was recorded onto D-1 tape also and provided to Data storage system using D-1 tapes.
As a result, designated or additional operators were needed for the tape handling operation.
Operators at data storage system also needed to manage lots of manual operation such as tape handling, data registration and so on.

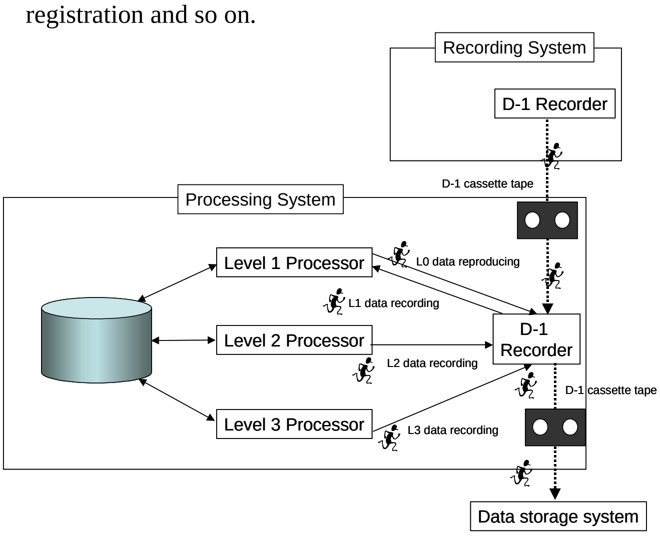

Fig. 4 ADEOS mission operation
(Standard data processing)

3-2-2 ADEOS-II mission

Fort ADEOS-II mission the processing system can input the processed data to the Data storage system via network. And also online data retrieval for re-processing is available.
ADEOS processing system was operated during daytime and weekday only but ADEOS-II processing system needs to be operated 24 hours, 365 days due to huge data volume.
Data input/output via network enables automatic operation without operator during nighttime and weekend.
Currently two operators are assigned to the processing system and one operator is assigned to Data storage system as one shift only. If operators are needed for 24hours and 365 days, additional 9 operators are needed (about $150,000 for one operator per year).

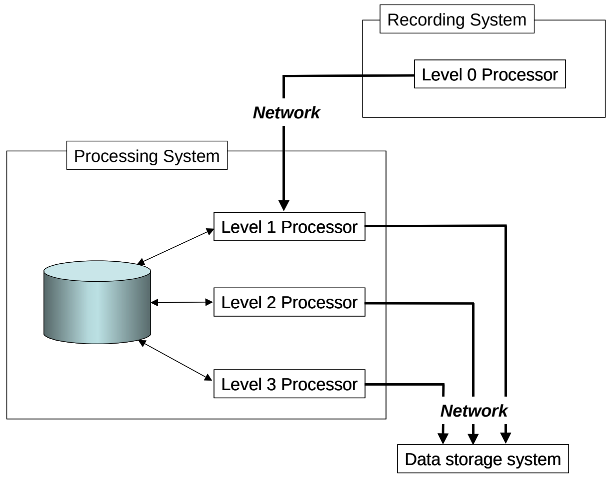

Fig. 5 ADEOS-II mission operation
(Standard data processing)

3-3 Product Order

3-3-1 ADEOS mission

Regarding product order, from data order to data distribution, there were several steps, such as order reception, processing request to related system, data processing, media conversion and data shipping.
For ADEOS mission these steps are managed by the different system. This needed more operators and also caused long time delay between order and data delivery.

3-3-2 ADEOS-II mission

For ADEOS-II mission, operation flow was re-considered. All the related steps are managed by the same system, Schedule Management Sub System

(SMSS) and step-by-step data management became available.
For this purpose, the idea of “Granule ID” was introduced.
“Granule ID” contains all the needed information for data management (satellite name, sensor name, path number, product name and so on) and is unique to each data/product. This enabled systematic and automatic operation and led to reducing operators.

3-4 Evaluation

Comparing ADEOS-II mission operation to previous mission operation (ADEOS) regarding the cost, the followings are the results.

1) Cost for operators and D-1 cassette tapes are reduced
2) Cost for new network is needed

In total, AMOS has succeeded to reduce the total operation cost because cost 1) is more than cost 2).
Furthermore, regarding the EOC common system such as Data storage system and SMSS, the numbers of operators decreased from 63 to 30 in total as a result of re-consideration of operation flow.
And these operation flow changes enabled “more user-friendly “ system. For example, the requirement shown in Table 3 is satisfied as a result of these changes. This is not directly related to cost reduction, but very important from the viewpoint of mission purpose.

4. Summary

The system development started in 1993. Though ADOES-II was launched three year later than the original schedule, the development was proceeded with minimum cost increase.
This system is very efficient and operational cost is also within the pre-defined budget. During the initial operation phase, it was confirmed that AMOS worked effectively as expected. And DTC was proved to be helpful and very effective to assess cost-effectiveness in each project.
Toward the data release to public users, AMOS is now evaluation phase.
The experience of the development of AMOS will be reflected to the next system.

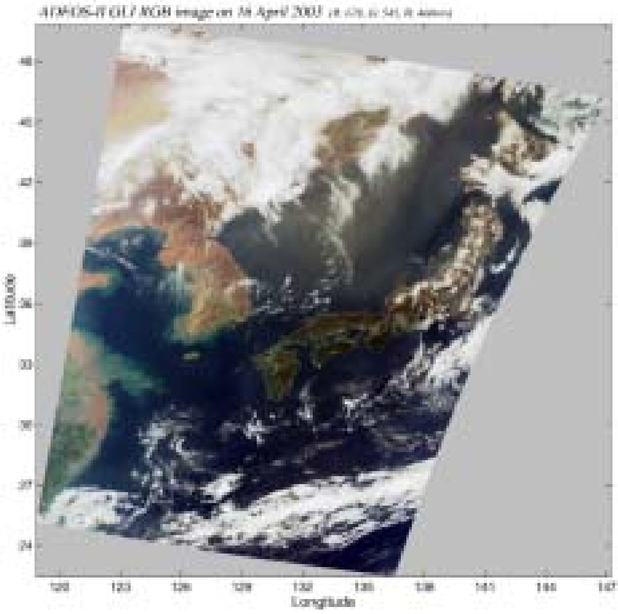

Fig.6 GLI Sample Image
(Kosa from Asian continent)

This image shows the Japanese Islands observed by GLI at 11:00 am, April 16, 2003.
Migratory high pressure can be clearly observed over western Japan and the Kinki region. The Japan Sea was covered with Kosa (dust) from the Asian continent.

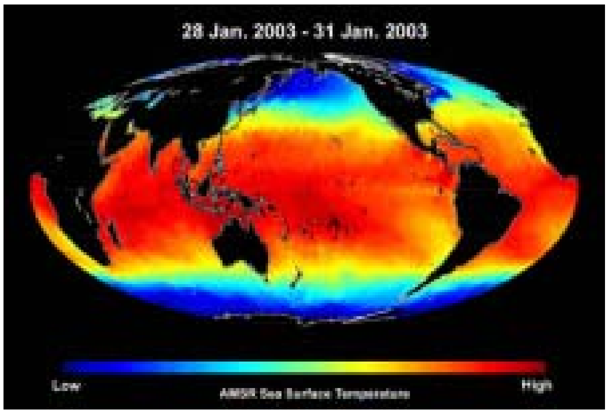

Fig.7 AMSR Sample Image
(Global SST distribution)

Four-day averaged global sea surface temperature (SST) distribution derived from AMSR data during January 28 and 31, 2003. It can be seen that the cold current streaming northward along the west coast of South America (Humboldt Current) is weakened by the El Nino event began in 2002. Because of the existence of warm currents (the Kuroshio Current and Gulf Stream), SST is relatively warmer in higher latitude along the east coast of continents in the Northern Hemisphere such as off east Japan and North America. In contrast, SST observed off California, which corresponds to the west coast of continent, is colder under the influence of the cold California Current even in the same latitude.

The microwave observation technique has the capability of observing SST through non-precipitating clouds. In addition to this, combination of AMSR and AMSR-E, which is the sister instrument (operational since June 2002) onboard NASA's EOS Aqua, provides more frequent measurement.